Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	|	
	|	ET Docket No. 04-352
Petition for Waiver of MBOA-SIG	|	

REPLY COMMENTS OF FREESCALE SEMICONDUCTOR, INC.

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Freescale Semiconductor, Inc. files these Reply Comments further to its opposition to the Petition for Waiver submitted by MBOA-SIG.[1] **The attached Technical Analysis is not an appendix, but is an integral part of this pleading.**

SUMMARY

MBOA seeks a waiver so it can test MB-OFDM frequency-hopping UWB devices with the frequency hopping running. These units hop over three bands with a short pause in between, so the signal occupies each band for about one-fourth the time. The waiver would permit the device to operate at four times the Commission emissions limits while active in each band, so the power in each band -- averaged over time -- complies with the limits. MBOA says the waiver is needed to allow its devices the same useful power as other forms of UWB, such as pulsed and

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[1] *Office of Engineering and Technology Declares MBOA-SIG Request for a Waiver of Part 15 for an Ultra-Wideband System to Be a "Permit-but-Disclose" Proceeding for Ex Parte Purposes*, Public Notice, ET Docket No. 04-352, DA 04-2793 (released Sept. 3, 2004) (erratum).

Freescale Semiconductor, Inc. began operations in 1953 as the semiconductor products sector of Motorola, Inc. It is a leading global semiconductor company with 10,000 end customers serviced and supported by 22,000 full-time employees in over 30 countries. Prior to spinning off Freescale as a separate company, Motorola acquired substantially all of the assets and intellectual property of XtremeSpectrum, Inc., a pioneering developer of ultra-wideband technology and active participant in the Commission's ultra-wideband rulemaking proceeding. Freescale now holds the assets and intellectual property Motorola acquired from XtremeSpectrum, and employs many former XtremeSpectrum key staff.

direct sequence, and thereby avoid discrimination against MB-OFDM. MBOA also asserts that devices under the waiver would cause no more interference to other spectrum users than pulsed or direct sequence UWB.

MBOA's rationale for the waiver and its non-interference claims both fail under close examination.

Far from giving MB-OFDM parity with other forms of UWB, the waiver would instead bestow on MB-OFDM a unique regulatory benefit. All UWB devices -- not just frequency hoppers -- operate in bursts. Pulsed and direct sequence UWB devices have to burst because each unit occupies the entire bandwidth, so they must take turns. Although these are compliance-tested to Commission limits with the transmitter locked on, in actual use the duty cycle of a single unit can rarely exceed 25%. That puts the average power in actual operation at several decibels below Commission limits. This is very similar to what MBOA objects to -- but all of UWB is in the same boat. The *status quo* keeps everyone on an equal footing. Allowing MB-OFDM to time-average emissions readings would let each such device operate right up to the Commission limits. Other UWB, cycling on and off in use, can at best average about 6 dB lower. The waiver would give MB-OFDM a large and unfair advantage in the marketplace.

The satellite industry has expressed fears that devices under the waiver could cause interference to C-band earth stations. If the high level of emissions during a pulse causes data loss, the quiet period afterward may not bring the data back, even though it lowers the average emissions. One MBOA member filed an analysis and simulation that claim to show little or no more interference from frequency hoppers than from pulsed UWB, but the work has serious errors that make the results meaningless.

Devices under the waiver would also threaten interference to public safety operations at 4.9 GHz and to transportation-related communications in the Dedicated Short-Range Communication Services at 5.9 GHz. The very brief high power levels used by MB-OFDM are 2-11 dB more interfering to these wideband receivers than other UWB, even if they appear to be compliant when time averaged.

In an important omission, MBOA fails to address the fact that communication using MB-OFDM requires two or more units in close proximity. Unlike pulsed and direct sequence UWB, nearby MB-OFDM transmitters can operate simultaneously. Each unit seeks out and transmits on channels left momentarily vacant by others. Under the waiver, a cluster of MB-OFDM units will thus tend to occupy all channels most of the time -- all at 6 dB over Commission limits.

This means a grant of the waiver is tantamount to raising the MB-OFDM emissions limits by 6 dB. The Commission has consistently refused to raise the emissions limits for other forms of UWB, on the ground that it first wants to gain practical experience. But there has been no experience as yet, because there are no communications UWB products on the market. And the Commission has expressed special concern about the unknown effects of interference from frequency hoppers measured with the hop running.

In short, MBOA has utterly failed to meet the burden of proof needed to justify the waiver.

The question of emissions limits was the most contentious single issue in the long, hard-fought UWB proceeding. If the Commission now seeks to revisit that question, it should not do so indirectly, under cover of this out-of-the-way waiver proceeding. The issues are sufficiently complex, and are of broad enough interest, to call for a public and transparent rulemaking.

Discussion

A. Introduction

A frequency-hopping ultra-wideband transmitter functions by "hopping" its signal from one wideband frequency channel to another. The Commission requires such devices to be tested with the hopping stopped, so the signal stays in one channel. MBOA-SIG seeks a waiver of that requirement so as to carry out compliance testing with the frequency hopping active.

MBOA offers two basic grounds for its request. Because the Commission's Rules were written for pulsed or direct sequence UWB, it says, the waiver is needed to eliminate "unintended regulatory hurdles"[2] against MBOA and allow it to "compete fairly."[3] And MBOA claims that devices certified under the waiver will not cause any more interference to licensed services than pulsed or direct sequence UWB.[4]

We show below that both assertions are wrong.

MBOA's modulation hops over three channels, with a little "off" time in between, so it occupies any given frequency band 26% of the time.[5] If measured with the frequency hopping stopped, as the rules require, the signal cannot exceed Commission limits. But if measured with the frequency hopping running, as MBOA requests, the signal could be almost four times as high

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2 Petition for Waiver at 2.

3 Petition for Waiver at 3.

4 MBOA also claims certain performance advantages. Petition for Waiver at 2. Freescale showed in its Opposition at (17-18) that the advantages are nonexistent.

5 Petition for Waiver at 2 n.3 & Attachment A.

as the limits (6 dB above). Yet because the signal is present in the band only 1/4 of the time, the time-averaged emissions would still qualify for certification.

The waiver request arises from a particular characteristic of the measurement process. UWB emissions are measured in a single 1 MHz region at a time.[6] Seen through that narrow window, an MB-OFDM transmitter indeed appears to be on only 26% of the time. But the transmitter is actually putting out excessive signal, somewhere in the spectrum, fully 78% of the time.

B. Pro-Waiver Comments Add Little Support.

Of the nine filings in support of MBOA, five are nearly identical, seemingly copied from a common source.[7] They merely parrot MBOA's claims without adding any new evidence or arguments. Another three supporters filed pleadings in their own words, but these likewise provide nothing new.[8]

Only one supporting submission even attempts a contribution. Philips Electronics North America presents an analysis that, in Philips' view, upholds claims of lower interference from MB-OFDM than from pulsed UWB,[9] and offers a simulation that, it says, shows interference into a QPSK receiver is no more than 2 dB worse from MB-OFDM than from other forms of UWB.[10]

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6 47 C.F.R. Sec. 15.521(d).

7 Alereon, Inc.; Cetecom S.A.; Hewlett-Packard Co.; Time Domain Corp.; Renasas Technology America, Inc.

8 Harris Corp.; WiLinx Corp.; WiMedia Alliance.

9 Philips Electronics North America Corp. at 3-14.

10 Philips Electronics North America Corp. at 17-22.

The attached Technical Analysis shows why both of these conclusions are incorrect. The Philips analysis relies on amplitude probability distributions (APDs) which, by their nature, ignore time scale effects, such as the time duration of an interference burst. This makes APDs incapable of distinguishing between the relative interference effects of MB-OFDM and pulsed UWB. The simulation likewise is defective. It starts by adding so much noise to the victim receiver that just a fraction of a decibel more would cause it to fail. Not surprisingly, that noise masks any differences in the interference effects between MB-OFDM and other types of UWB, rendering the results uninformative.

Nothing in the comments filed in support of MBOA advances the case for a waiver.

C. The Record Strongly Supports Denying the Waiver

The pleadings present several dispositive grounds for denying MBOA's waiver request.

1. A waiver will result in unfair competitive advantage. MBOA claims the waiver is needed to avoid regulatory discrimination. Precisely the opposite is true. The waiver would give MBOA a valuable unearned advantage in the marketplace over other forms of UWB.

MBOA wants to quadruple the emissions during the 1/4 of the time its signal is active in a given channel, arguing that average emissions would then match those from other UWB. That might be a fair outcome if other UWB devices transmitted continuously. But they do not. Because all such devices must share a single channel, they send data in bursts, one packet at a time, listening for acknowledgment and making room for other transmissions in between. Duty cycles for each device rarely exceed 25%.

Yet pulsed and direct sequence UWB nonetheless must be tested with the transmitter locked on -- the condition that MBOA seeks to avoid. Because pulsed and direct sequence UWB is intermittent in actual use, yet compliance-tested in a state of continuous operation, its power in actual use is at least 6 dB below the compliance measurements. That is very similar to the situation MBOA complains of -- and seeks a waiver to relieve. A grant of the waiver to MBOA, but not to other UWB, would excuse MBOA from a constraint that continues to limit everyone else. And it would give MBOA an unearned 6 dB competitive advantage over other UWB.[11] In the marketplace, power translates to greater range, greater data capacity, or a combination of the two. Ironically, even though MBOA claims a waiver is necessary to alleviate discrimination, in fact the waiver would impose precisely the same discrimination against the rest of the industry.

The waiver would also grant MB-OFDM a second form of competitive advantage: the ability to subject other UWB devices to 6 dB more interference than MB-OFDM receives from other UWB.

We think the waiver is ill-advised; but if the Commission grants one, it must do so in a technology-neutral manner. This means allowing any UWB device -- not just MB-OFDM -- to time-average when testing for compliance.[12] Any other result would unfairly favor one segment of the industry over others.

2. A waiver will cause interference to C-band receivers. All of the reliable evidence shows MB-OFDM is more interfering to C-band satellite receive operations than pulsed or direct sequence UWB. The satellite industry concurs. The Coalition of C-Band Constituents

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[11] *See* Motorola, Inc. at 8.

[12] This requires waiving the requirement that a gated UWB system be tested with the gating locked on. 47 C.F.R. Sec. 15.521(d).

notes that MB-OFDM emissions are 6 dB above Commission limits during a pulse.[13] And the Satellite Industry Association points out that data lost during a pulse may be gone forever.[14] The silent period after the pulse brings down the average emissions, but may not be able to recover the lost data.[15]

The Commission established the current UWB limits to be safe for satellite operations. No one disputes that a waivered MB-OFDM transmitter will put out higher emissions during a pulse than the limits presently allow. No one can seriously dispute that the higher-powered pulse, while it is on, is more interfering than compliant UWB. Hence, there is a region around each earth station where a waivered MB-OFDM transmitter would cause data loss during a pulse, but a compliant UWB device does not. For some earth stations, particularly those pointing steeply upward, that region may be so small and so close to the earth station as to be of no consequence. But for others, including earth stations at low elevation angles, the region could be accessible to UWB users. Within those regions, a grant of the waiver would produce a direct threat of harmful interference to satellite communications.

3. A waiver threatens interference to 4.9 GHz public safety and 5.9 GHz DSRC. The Commission recently adopted rules for public safety operations in the 4940-4990 MHz band, and for transportation-related Dedicated Short-Range Communication Services

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[13] Coalition of C-Band Constituents at 4.

[14] Satellite Industry Ass'n at 6.

[15] Similarly, decaWave (at 1-3) provides calculations showing MB-OFDM causes more interference into BPSK than pulsed UWB, and extends that result to other modulation schemes.

(DSRC) at 5.850-5.925 GHz.[16] Both services will use wideband OFDM technology.[17] Lucent Technologies Inc., filing in the UWB proceeding, presented interference analyses for several types of victim wideband digital receivers, including a wideband OFDM wireless system similar to those planned for 4.9 GHz Public Safety and DSRC services.[18] Lucent concludes that UWB signals with very short burst times (such as MB-OFDM and the gated systems analyzed by Lucent) cause higher levels of interference than do other UWB systems. Specifically, Lucent showed an effective increase in interference range for short-burst UWB devices in the presence of several types of wideband digital receivers. The increase amounted to between 2 and 11 dB, depending on the characteristics of the victim systems and the UWB device itself. It results from the higher peak power levels used by burst UWB operations that occur even when such devices comply with time averaging, as MBOA proposes.[19] In short, Lucent has identified a potential for increased interference for wideband digital systems from MB-OFDM operating under the proposed waiver.

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16 *The 4.9 GHz Band Transferred from Federal Government Use*, 18 FCC Rcd 9152 (2003); *Dedicated Short-Range Communication Services in the 5.850-5.925 GHz Band*, 19 FCC Rcd 2458 (2004).

17 John Powell, *NPSTC and 4.9 GHz Band Presentation*, California State APCO Conf. (May 2004), available at http://www.publicsafetycommunications.org/Wi-Fi.php. DSRC uses the 802.11a physical layer and a half-rate 802.11RA version. Work is underway to standardize this approach as IEEE 802.11p.

18 Lucent Technologies Inc. in ET Docket No. 98-153 (filed Sept. 12, 2000). Although the waveforms to be used for DSRC and Public Safety systems will be based on 802.11a OFDM, they will likely have bandwidths of 5-10 MHz, somewhat less than the 16.5 MHz bandwidth OFDM signal analyzed by Lucent.

19 Lucent Technologies, Inc. at 2 and Annex A2.

4. ***A waiver will enable high-power aggregation***. MBOA's request relies on the proposition that an MB-OFDM device operates at elevated levels only 26% of the time. But a single such device is useless. At least two are needed for communication, and a network is likely to include several. MBOA insists on evaluating interference "under normal operating conditions."[20] That requires looking at multiple units.

UWB signals cannot occupy the same frequency at the same time. When devices operate in close proximity, the media access control layer in each one seeks out vacant spectrum on which to transmit. Because a pulsed or direct sequence UWB device uses the entire bandwidth, it waits for all nearby similar devices to fall silent. The units take turns, like speakers in a conversation. But MB-OFDM devices behave very differently. Each one hunts among the various channels and transmits on time slots momentarily left vacant by other devices. Together, the devices tend to fill all the channels most the time, somewhat like people shouting in a crowd. Under the waiver, each of these simultaneous transmissions is at 6 dB above Commission limits. *The result is near-continuous transmission on all channels at levels well in excess of the rules.*[21] This would put many classes of receivers at higher risk.

D. MBOA Cannot Meet Its Burden of Proof.

The Commission's Rules presumptively serve the public interest. Therefore, a waiver applicant has the "burden of establishing that the public interest is better served, on the facts

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20 Petition for Waiver at 3 (emphasis in original).

21 *See also* Ex Parte Statement of Motorola, Inc. at 3 (filed Sept. 29, 2004) (deliberate synchronization under the waiver raises emissions levels to 6 dB above Commission limits). As shown in text, the outcome is almost the same even without deliberate synchronization.

presented, by a waiver" than by the existing rules.[22] The precedents consistently point to a "heavy" burden of proof.[23] *WAIT Radio v. FCC*,[24] the legal basis for Commission waivers,[25] warns that the petitioner faces a "high hurdle even at the starting gate."[26]

The burden is especially steep where, as here, the proponents advance arguments similar to those already considered and rejected by the Commission in developing the rules sought to be waived. The "special circumstances" justifying the waiver must go beyond the considerations raised in the rulemaking.[27] MBOA cannot do that.

Moreover, the reviewing courts give the Commission far more discretion in denying a waiver than in granting one. A rejection will not be overturned "unless the agency's reasons are so insubstantial as to render that denial an abuse of discretion."[28] A grant, on the other hand, must not only explain why a deviation from the rules better serves the public interest, but must also "articulate the nature of the special circumstances to prevent discriminatory application and

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[22] *Carolina Broadcasting Co.*, 18 FCC 2d 482, 483 at para. 5 (1969). *See also Federal State Board on Universal Service -- United States Cellular Corp.*, 19 FCC Rcd 12418 at para. 6 (2004); *Petition for Waiver of International Settlements Policy*, 5 FCC Rcd 4618, 4621 at para. 19 (1990).

[23] *ITFS -- Second Report and Order on Reconsideration*, 59 R.R.2d 1355 at para. 52 (1986); *Telecommunications Relay Services*, 29 C.R. 1230 at para. 26 (2003).

[24] 418 F. 2d 1153 (D.C. Cir. 1969) (subsequent history omitted).

[25] *2002 Biennial Regulatory Review*, 18 FCC Rcd 13620 at para. 85 n.130 (2003).

[26] *WAIT Radio*, 418 F. 2d at 1157.

[27] *Industrial Broadcasting Co. v. FCC*, 437 F. 2d 680, 683 (D.C. Cir. 1970).

[28] *Omnipoint Corp. v. FCC*, 213 F. 3d 720, 723 (D.C. Cir. 2000)

to put future parties on notice as to its operation."[29] MBOA has simply failed to provide the support the Commission would need to meet these requirements.

In short, the meager grounds in MBOA's petition are insufficient to justify the waiver it requests.

E. The Proceeding Raises Issues Beyond the Scope of a Waiver.

We have shown that the waiver would cause near-continuous average emissions on all channels simultaneously that approach 6 dB above the Commission's limits. As a practical matter, grant of the waiver is equivalent to raising the UWB emissions limit by 6 dB.

If the waiver proponents had requested this outcome in so many words, they might not have gotten far. Emissions limits were the central issue throughout the four years of the UWB proceeding, argued back and forth in hundreds of submissions. After the Commission ruled, some parties sought reconsideration to request higher limits.[30] The Commission responded:

> [W]e continue to believe that major changes should not be made to the UWB rules *until more experience is gained with the operation of UWB devices*.[31]

That was in March 2003. Nothing has changed since then. We still have no practical experience with communications UWB devices, because none are yet on the market. If a rule change by NPRM would have been premature 18 months ago, then the same rule change by

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[29] *Northeast Cellular Telephone Co., L.P. v. FCC*, 897 F. 2d 1164, 1166 (D.C. Cir. 1990).

[30] *E.g.*, *Ultra-Wideband Transmission Systems*, 18 FCC Rcd 3857 at para. 21 (2003) (*MO&O & FNPRM*) (ground penetrating radar); *id*. at para. 50 (indoor UWB devices at 960-1610 MHz).

[31] *MO&O & FNPRM* at para. 54 (emphasis added).

waiver is equally so today. As Cingular Wireless aptly put it, the Commission would be "flying blind."[32] And, because UWB shares bandwidth with many other services, the potential consequences of getting it wrong are enormous.[33]

The Commission has been particularly cautious about frequency hopping UWB. The *First R&O*, discussing frequency hopping together with swept frequency techniques, noted both the lack of measurement procedures and the difficulty of evaluating potential interference from measurements taken with the sweep active (or the frequency hopping running).[34] These uncertainties are what prompted compliance testing of frequency hopping UWB with the hopping stopped[35] -- the requirement MBOA seeks to have waived. A year later, after others asked for special rules to accommodate frequency-hopping UWB systems, the Commission responded:

> [T]he inclusion of a frequency hopping modulation technique at this time is beyond the scope of the issues addressed thus far in this proceeding.[36]

The Commission did, however, raise the issue for public debate in a Further Notice of Proposed Rulemaking.[37]

That is the best approach here. What looked at first like a minor fix to the measurement procedures turns out, on closer examination, to rewrite the single most controversial aspect of the

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32 Cingular Wireless LLC at 2. *See also* Motorola, Inc. at 9.

33 Cingular Wireless LLC at 2.

34 *Ultra-Wideband Transmission Systems*, 17 FCC Rcd 7435 at para. 32 (2002) (*First R&O*).

35 *Id.*

36 *MO&O & FNPRM* at para. 54 (referring to vehicle radar systems).

37 *MO&O & FNPRM* at paras. 156-161.

UWB rules. The issues deserve a wider airing than a technical waiver proceeding can provide. Moreover, as the Satellite Industry Association points out, the Commission should not waive a safeguard without imposing alternative measures to prevent interference.[38] If indeed there is a fundamental problem with the measurement procedures, as MBOA suggests, then the solution is not haphazard waivers, but better procedures.[39] Those are best taken up in a rulemaking,

CONCLUSION

The waiver requested by MBOA threatens interference to licensed users. Instantaneous emissions from even a single unit are more likely to cause data loss in C-band satellite receivers than from other UWB devices. Worse, because MB-OFDM units transmit in one another's vacant channels, all channels tend to become occupied simultaneously at over-limit levels, threatening receivers across the spectrum.

The waiver would give MB-OFDM devices a strong regulatory advantage over other types of UWB. Because the Commission's Rules did not contemplate bursty emissions, says MBOA, it needs the waiver to level the playing field. But all UWB devices are bursty in operation, so that all produce far less average power in operation than in compliance tests. Granting a waiver solely to MBOA would effectively raise its emissions limit by 6 dB over other forms of UWB. (Indeed, this may have been among MBOA's motives in selecting its modulation.)

Action on a waiver would be premature, in view of ongoing testing by NTIA and the Commission, and especially considering the complete lack of experience under the current rules.

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38 Satellite Industry Ass'n at 5.

39 Satellite Industry Ass'n at 5.

But if the Commission is determined to revisit the contentious issue of UWB emissions, it should acknowledge that the issues are too complex and far-reaching for a waiver proceeding. Any revisions should be conducted out in the open, under a Notice of Proposed Rulemaking.

Respectfully submitted,

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Attachment A

A Technical Analysis of Philips Electronics North America Corporation Comments in Support of The MBOA-SIG Petition for Waiver

CONTENTS

1. Introduction

In this attachment, we examine the comments of Philips Electronics North America Corporation (Philips) in relation to its two main considerations, namely: the thesis that an APD analysis by itself can quantify receiver susceptibility, wherein the APD analysis is claimed to prove that MBOA is less interfering[1], and second, an analysis and simulation of an uncoded (no FEC) QPSK system wherein its is claimed that the MBOA waveform is only 2 dB more interfering than continuous noise[2].

In regard to the first consideration, we illustrate why APD analysis alone is not a conclusive means of determining interference susceptibility for wireless systems in general, and why it cannot be used to justify the waiver.

In regard to the second consideration, we show how the QPSK simulation is flawed. We then provide additional simulation results that correct the flaws and show that MB-OFDM causes significantly more interference than shown by Philips.

In short, nothing in the Philips comment advances the case for a waiver.

2. APD Analysis and Susceptibility

The final conclusion by Philips that

> "MB-OFDM employing a sequence of 3 bands is shown to create no more potential for interference than the impulse transmitters anticipated by the UWB rules"[3]

is far beyond what the APD analysis could possibly support or justify.

2.1. Erroneous Assumptions in APD Analysis

The thesis of the APD section of the Philips filing is that APD's reflect susceptibility. The Philips report assumes that the peak values of the APD plot will determine the performance of the victim receiver. In other words, the peak value of APD is considered the interference indicator. This is simply not true.

Many key parameters required to predict susceptibility are not contained in an APD. An APD is blind to temporal/spectral features of signal, such as the duration of an interference burst, or how often an interference burst happens. An APD is also blind to the modulation efficiency and FEC coding of the victim signal. It cannot capture the slope or position of a BER curve. On the contrary, an APD plot only captures amplitude statistics that occur over a long period of time—enough time to capture the rarest events at the lowest probability points on the graph. An APD does not represent any temporal characteristic of the signal being analyzed. So it stands to reason that the APD cannot predict receiver interference susceptibility, particularly since an APD captures only one dimension of the multi-dimensional information necessary to analyze a receiver's response to a selected interfering signal.

In its technical description of how APD's work, the NTIA pointed out the same thing[4]

[1] Philips Electronic North America Corp. at 3-14.

[2] Philips Electronic North America Corp. at 17-22.

[3] Philips Electronic North America Corp. at 23

> “Many modern digital receivers use elaborate error correction and time-interleaving techniques to correct errors in the received bit sequence. In such receivers, the corrected BER delivered to the user will be substantially different from the received BER. Computation of BERs in these receivers will require much more detailed interference information than is contained in the APDs. For example, second-order statistics of noise amplitudes describing the time of arrival of noise amplitudes may be needed.”

In addition to this point, the authors of the Philips comment made several other serious mistakes. Philips did not take advantage of the APD descriptions or computer codes published by NTIA, which define the scope of generally accepted engineering principles in this discipline. Additionally, Philips chose to plot their results in a non-conventional manner, making it difficult to compare the presented APD plots with other APD analysis. [5] In this case, however, neither of the preceding errors matter because the entire thesis upon which Philips bases their conclusion is flawed.

2.2. Examples of APD Plots Not Indicating Interference Susceptibility

To facilitate an appreciation of how the thesis that APD’s reflect susceptibility is wrong, a very simple counter example is presented. The example illustrates how two interfering signals can have identical APD plots, yet cause significantly different BER impacts on the same receiver.

Consider two very simple generic waveforms, the first signal is gated noise[6], and the second is a signal that is the sum of impulsive noise and continuous noise[7].

Figure 1 is an oscilloscope plot of the signals. It shows how different these waveforms are in the time domain. We have included continuous Gaussian noise for reference. All of the signals are adjusted to have identical RMS power. Figure 2 shows the APD plots for these very different signals. The APD plots of the two test signals are essentially identical. Figure 3 shows the BER performance of a QPSK receiver using a rate 7/8 K=7 Viterbi decoder. It shows how these waveforms, even with nearly identical APD’s, have significantly different interference affects. The position and slopes of the bit error rate curves are completely different.

From this illustration, it is easy to see how an APD analysis does not provide clear or complete insight into the interference potential of either signal. It cannot prove anything about whether one signal is more or less interfering than another. Two interfering signals

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[4] NTIA Report 01-383 Appendix A, page A-20, Jan 2001.

[5] The APD analysis was not done in accordance with APD techniques described by NTIA in UWB proceedings (e.g. NTIA Report 01-383, Appendix A) nor with the Matlab APD analysis code that NTIA/ITS provided to the IEEE 802.15.3a Task Group.

[6] The gated noise signal can be written mathematically as $s_g(t) = h(t) * \sum_k n(t) g(t - kT_g)$ where *n*(*t*) is a continuous additive white Gaussian noise process (AWGN), *g*(*t*) is the gating function with period *Tg*, (*g*(*t*) has a ~5% duty cycle for this example), and *h*(*t*) is the impulse response of the receiver filter (and APD filter).

[7] The impulsive signal can be written mathematically as $s_i(t) = \sum_k n(k) h(t - kT_i)$, where *n*(*k*) is a discrete white Gaussian noise process weighting each pulse, the impulse period is *Ti* is approximately 5% of reciprocal of the receiver bandwidth, and *h*(*t*) is the same as the first signal.

with identical APD plots can have completely different impact on the BER of a receiver. Beyond this illustration, it should be noted that two signals with identical APD's can have completely different spectral properties. Conversely, two signals with identical spectral properties can have completely different APD plots. Thus, the thesis of the Philips filing – that APD plots reflect susceptibility – is shown to be wrong.

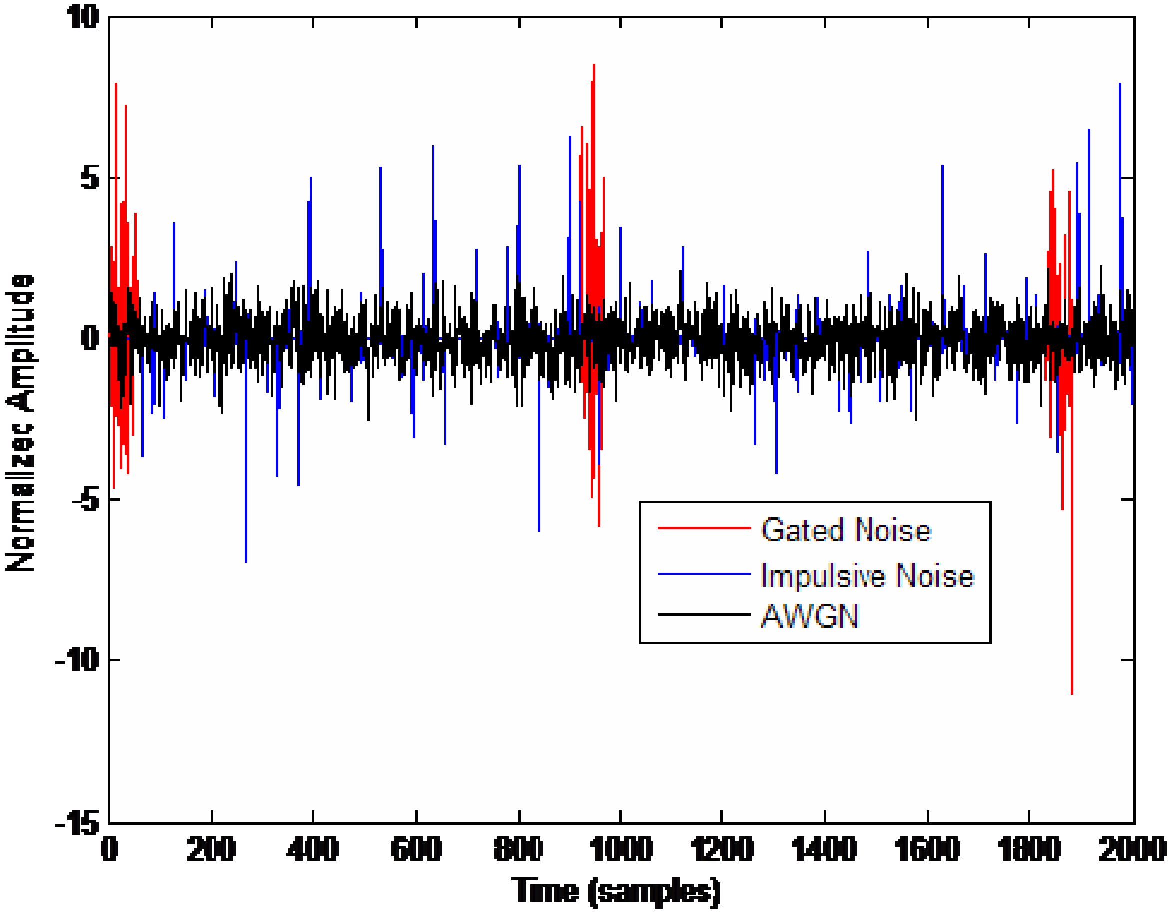

Figure 1. Time domain plots of the gated noise signal and an impulsive plus added noise signal, with continuous Gaussian noise for reference. (all have identical RMS power)

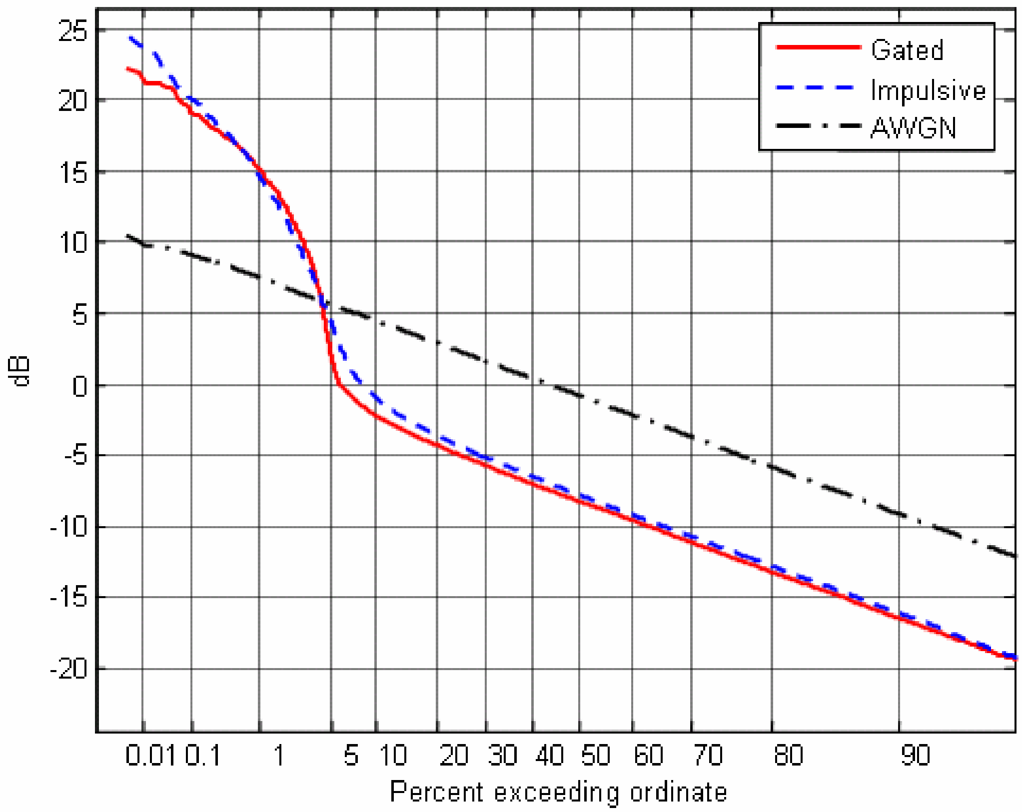

Figure 2. APD plots showing nearly identical curves for a gated noise signal and an impulsive plus added noise signal, with continuous Gaussian noise for reference (all have identical RMS power)

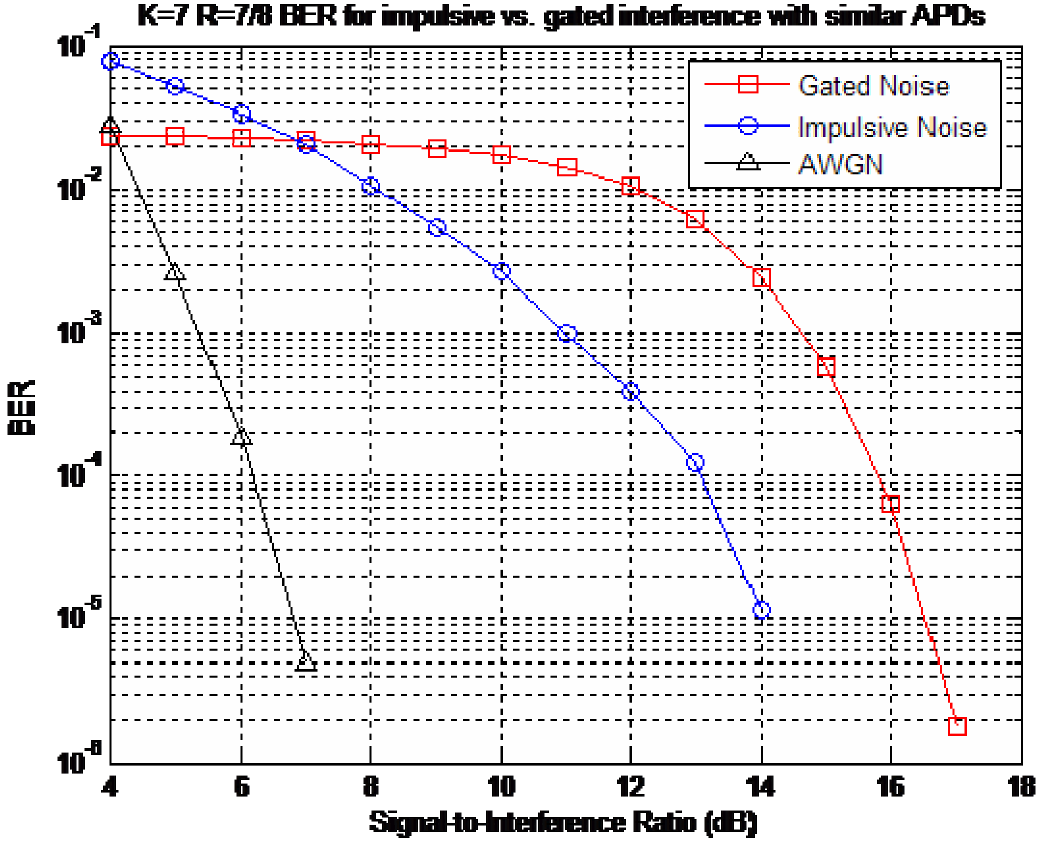

Figure 3. Bit-error-rate curves for a receiver using rate 7/8 convolutional code showing the very different error performance for two noise signals that had nearly identical APD plots.

3. QPSK System Performance

In its discussion of the QPSK simulation, Philips drops the claim of *lower interference for MB-OFDM*, and instead concludes that for MB-OFDM the additional "impact was reduced to below 2 dB in realistic scenarios".[8] We show that even this conclusion is flawed.

Because there are no closed form solutions to the non-Gaussian statistics of the MBOA interference, simulations and measurements must be used assess its impact. As a result, only the plots of results of simulations have the potential to be relevant.

3.1. Unrealistic Operational point

Operating a system at an ultra-low SNR places a victim receiver system on the verge of breaking, without any additional interference. This is not a realistic operating scenario and thus, leads to an incorrect conclusion. The fact that the system is on the verge of breaking without interference masks any susceptibility differences between differing interference waveforms. Yet this high-noise (ultra low SNR) case is what Philips chose to use. No commercial, private, or military receiver system operates under the conditions selected by Philips since communication system reliability would be severely compromised if such an unrealistic operating point was selected.

[8] Philips Electronic North America Corp. at 23.

An uncoded QPSK system requires a threshold Eb/No of 9.6 dB, assuming Gaussian noise, to provide a BER of 10^{-5}. Relative to this threshold Eb/No of 9.6 dB, Philips chose to operate the system at an Eb/No of 10 dB—only 0.4 dB above its sensitivity threshold.

Philips claims 0.4 dB represents a "healthy link margin"[9]. We strongly disagree. This ultra low SNR-margin scenario does not qualify as a reasonable scenario because there is not enough margin to make a useable system. The BER is on the verge of being unacceptable with no interference. Interference that represents only a tiny fraction of the power in the background noise (the interference power that is only one-tenth of the power of the background noise) will, in this case, raise the BER above the unacceptable threshold. The use of the unrealistic Eb/No with 0.4 dB of margin culminates in showing only a 2 dB performance differential between the MB-OFDM and AWGN case because of the masking effect. The masking effect is directly related to the unrealistic operating point selected by Philips.

Real interference scenarios always imply some finite SNR, typically with enough margin to support the intended system robustness and quality of service. For example, the ETSI specification[10] for minimum SNR for C-band systems is based on very steep BER curves and being 3 dB above the threshold of "Quasi error free" (QEF) (about 10^{-10} bit error rate). Typical C-band installations are sized such that the SNR is 3 to 6 dB above the minimum specification—giving an operating margin of 6 to 9 dB. In general (i.e. not C-band), receivers rarely operate with the incredibly steep BER curves that C-band systems use. As a result, most radio systems require more than the 6 to 9 dB margin used in C-band systems.

3.2. Corrected Analysis

In reality, if the more typical 6-10 dB of margin is used in the Philips simulation, there is a 4 to 5 dB differential between AWGN and MB-OFDM. Figure 4 illustrates this fact by showing the 10dB Eb/No (i.e. 0.4 dB margin) curve provided by Philips, along with a corrected simulation that shows 16 dB, 20 dB, and no-noise Eb/No curves (i.e. a baseline of 6 dB, 10 dB, and infinite margin). The plots show how the difference in interference between continuous noise and bursted MBOA noise are quite significant even at with a low link margin of only 6 and 10 dB.

It is clear from these plots that Philips fails to show that the waiver would cause no more interference. The 4 to 5 dB added degradation is very close to the 25.8% duty-cycle calculation of 10*log10(1/0.258)=5.9 dB. The technically justifiable conclusion is that the waiver will increase the interference by almost the full amount of the increase in power that would be allowed under the waiver. So the waiver fails the interference test.

[9] Philips Electronic North America Corp. at 21. Philips states that this operating point would be conservative for a different system, a *coded* QPSK system, and then proceeds to use it for the *uncoded* QPSK system anyway. This is inappropriate because a coded QPSK system could have much lower (4-5 dB or more) SNR requirements.

[10] The ETSI standard for Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation (EN 300 421, dated 1997-08, annex D) indicates that the minimum CNR for acceptable performance is 8.4 dB. This value, the minimum acceptable level, is about 3 dB above the minimum level for the desired operating point of "Quasi-Error-Free" performance for satellite video receivers. In addition, this level of 3 dB minimum margin does not provide any allowance for interference.

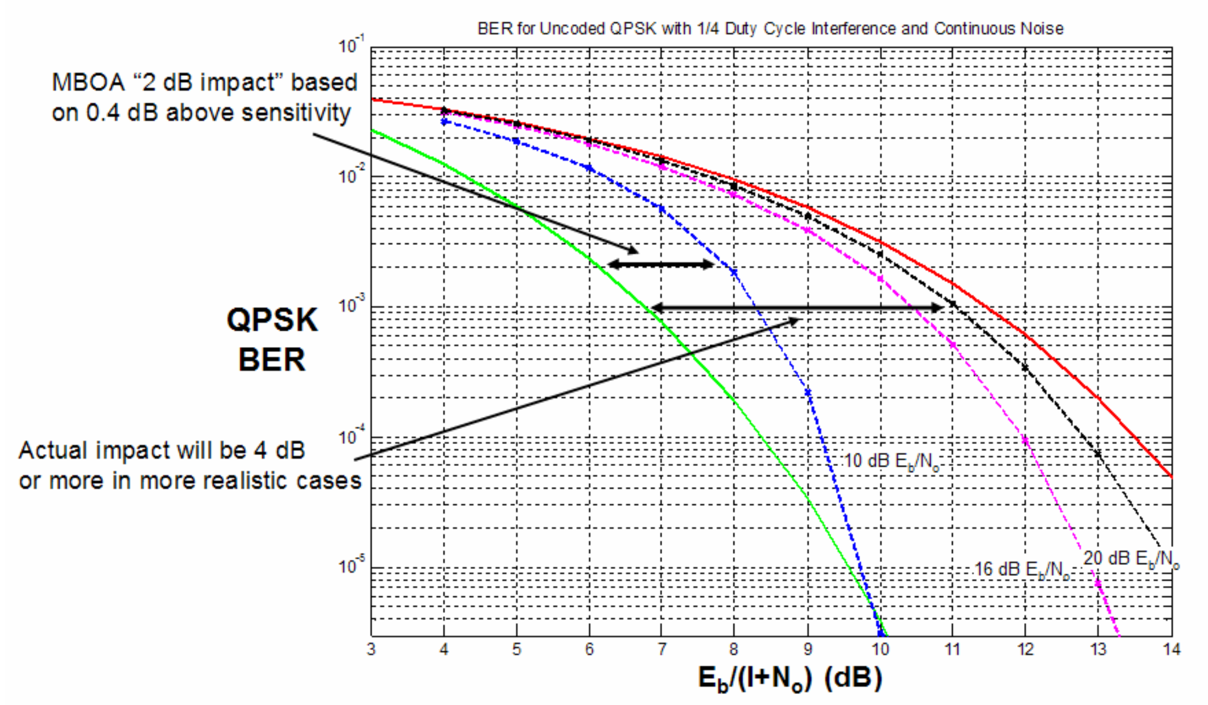

Figure 4. Uncoded QPSK performance in presence of thermal noise and interference.

4. Conclusions

We have shown that the technical data contributed by Philips in their submission is flawed and so provides no justification for granting the waiver. Philips fails to show that the waiver would cause no more interference than anticipated by the Commission under the original Report and Order and pursuant to the current Rules. Philips also fails to show that granting the waiver is in the public interest.

The Philips thesis that APD plots reflect susceptibility is flawed. Philips' conclusion that "MB-OFDM employing a sequence of 3 bands is shown to create no more potential for interference than the impulse transmitters anticipated by the UWB rules" is far beyond what APD analysis can possibly support or justify.

Philips' simulation of a QPSK receiver is flawed because it used an ultra-low baseline SNR with only 0.4 dB of system operating margin (i.e. it was 0.4 dB from breaking without any interference). This low level represents a poor choice that masks the interference effects of an MB-OFDM waveform. The low level used does not reflect margins listed in specifications or margins that are used in practice. We showed that if the SNR margin was increased to a reasonable operating point, then the MBOA signal causes a 4 to 5 dB increase in interference—not 2 dB as claimed by Philips.

In conclusion, it is clear that nothing in the Philips comments supports the granting of the MBOA waiver request.

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